

1 limited to solid state lasers of Er:glass, Ho:YAG, Er:YAG, Er:YSGG, infrared gas lasers,
2 solid-state lasers converted by optical parametric oscillation (OPO); (b) ultraviolet (UV)
3 lasers having wavelength range of about (190 – 355) nm, such as ArF (at 193 nm) and XeCl
4 (at 308 nm) excimer lasers and solid-state lasers using harmonic generation from solid-state
5 lasers of Nd:YAG, Nd:YLF and Alexandrite lasers frequency conversions; (c)
6 semiconductor diode lasers at about 980 nm, (1.3-1.55) microns, and (1.8-2.1) microns; (d)
7 diode-pumped solid state lasers having wavelength range of about (190-355) nm and (2.7-
8 3.2) microns such as diode-pumped Er:YSGG, Er:YAG, Nd:YAG and Er:glass. and; (e)
9 diode lasers having wavelength at about 980 nm, 1.5 microns, and 1.9 microns.

10 According to one aspect of the present invention, the preferable scanning laser energy per
11 pulse on scleral surface is about (2-20) mJ in IR lasers and about (0.5 – 2.0) mJ in UV lasers.
12 Focused spot size of about (0.1-0.5) mm in diameter on the corneal plane is achieved by the
13 focusing lens 3 which consists of at least one spherical lens. The other preferred laser
14 parameter of this invention is the laser repetition rate range of about (5-100) Hz which will
15 provide reasonable surgical speed and minimum thermal effects. The focused beam may be
16 scanned over the scleral surface to ablate various patterns to achieve the desired sclera
17 expansion.

18 Referring to Fig. 2(A), the laser output from the fiber end having wavelength 2 is
19 connected to the hand-piece 5 and a flat fiber tip 6 such that the output laser beam from the
20 end of the fiber tip is a round-beam with a pre-determined spot size of about (0.1-0.5) mm.
21 Fig. 2(B) shows similar structure to Fig. 2(A), except the output round-spot beam is re-
22 focused by the spherical shape of the tip. Fig. 3 (C) shows the output beam 2 is guided by a
23 conical shape tip such that the beam size at the end of the tip is reduced. Fig. 2(D) shows
24 that the output beam is reflected by 90-degree by a coated fiber tip. Finally Fig. 2(E) shows
25 an output beam spot is a slit-shape having a size of about (0.1-0.5) x (1.5-3.0) mm formed by
26 a cylinder lens attached to the end of the fiber tip.

27 Fig. 3 shows an eye 7 of a presbyopic patient with ablation patterns 9 generated on the
28 scleral area about (0.5-1.0) mm posterior to the corneal limbus 8. The preferred patterns of
29 this invention include a ring-spot having at least one ring with at least 3 spots in each ring,
30 and a radial-pattern having at least 3 radials. The preferred area of the ablation is defined
31 within two circles having diameters about 10 mm and 14 mm posterior to the limbus along
32 the radial direction of the scleral. We should note that a radial ablation pattern on the scleral
33 surface may be generated either by an automatic scanning device or by manually scan the
34 fiber tip by a surgeon who hold the hand piece. For the situation of the slit fiber-tip, the
35
36

1 surgeon may easily generate the radial patterns without moving the tip.

2 The ablation depth of the sclera ciliary tissue is about (400-700) microns with each of the
3 radial length of about (2.5 - 4.0) mm adjustable according to the optimal clinical outcomes
4 including minimum regression and maximum accommodation for the presbyopic patients.
5 The preferred radial ablation shall start at a distance about (4.0 – 5.5) mm from the corneal
6 center and extended about (2.0-4.0) mm outside the limbus. The preferred embodiments of
7 the radial patterns on the sclera area include at least 3 radial lines or ring-dots in a
8 symmetric geometry as shown in Fig. 3.

9 Still referring to Fig. 3, the preferred embodiments to generate the radial patterns on the
10 sclera area include the following examples. (A) Scan the round laser spot of about (0.2- 0.5)
11 mm in diameter produced from the fiber tips in the radial directions to generate each of the
12 radial lines. Generation of the radial patterns may be done either manually moving the fiber
13 tip along the cornea radial direction or by an automatically a scanner or translator. (B) Use a
14 focused slit-beam to generate the radial lines. In case (B), a scanning device is not needed
15 and each of the radial lines may be generated by the slit beam directly.

16 One preferred embodiment is to coagulate the conjunctiva layer and then cut (by a knife) a
17 half-circle over the conjunctiva surrounding the limbus with a diameter about 10 mm which
18 is then pushed aside in order for the ablating laser to cut the sclera layer underneath. It is also
19 possible to use the ablating laser to cut the conjunctiva layer which however may take a
20 longer time than cutting by a knife. Another preferred embodiment is not to open the
21 conjunctiva layer, but to insert the fiber tip through the conjunctiva layer and ablate the
22 sclera tissue underneath such that the procedure is done non-invasively. To do this
23 procedure, the conjunctiva layer may be lifted to generate the “gap” for fiber tip to insert into
24 the gap and ablate the desired patterns underneath. Additional advantages of this invasive
25 method is to avoid or minimize bleeding or infection. We note that most of the bleeding is
26 due to cutting of the conjunctiva tissue rather than the laser ablation of the sclera tissue.

27 While the invention has been shown and described with reference to the preferred
28 embodiments thereof, it will be understood by those skilled in the art that the foregoing and
29 other changes and variations in form and detail may be made therein without departing from
30 the spirit, scope and teaching of the invention. Accordingly, threshold and apparatus, the
31 ophthalmic applications herein disclosed are to be considered merely as illustrative and the
32 invention is to be limited only as set forth in the claims.